Environmental Studies in the Use of Accothion for Spruce Budworm Control

by

State of Maine, Department of:
Forestry
Agriculture
Inland Fisheries and Game
Health and Welfare
Sea and Shore Fisheries

University of Maine

U.S.D.I. Bureau of Sport Fisheries and Wildlife

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This joint report was compiled by a three-man coordinating committee selected by the authors of these special studies. Questions or comments on specific points should be addressed to the author(s). Additional copies of this joint report or general information can be obtained from the coordinating committee chairman.

Robley W. Nash
Maine Forestry Department
Augusta, Maine

John W. Peterson
U.S.D.I., Bureau of Sport Fisheries and Wildlife
Boston, Massachusetts

John F. Chansler, Chairman
U.S.D.A. Forest Service
Portsmouth, New Hampshire

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ABSTRACT

Application operations were preceeded by extensive planning and pre-cautionary measures. Base was at the Presque Isle Airport with the full operations crew living together as a unit at nearby facilities. The two applications were made in the period May 29 - June 15 inclusive. Direct costs were $1.194 per acre, addition of indirect costs or overhead brought this figure to $1.355.

Men assigned to hazardous areas at the airport facility were monitored for exposure to the insecticide chemical. Three blood tests were made on each man for plasma cholinesterase activity, the results showing no toxic exposure of any individual to the insecticide. The total aspect of equipment, drum, and area decontamination was supervised. A recommendation concerning elimination of drum decontamination was made.

Effects of the insecticide treatment throughout the treated area were determined from pre- and post-treatment foliage collections from trees at 86 locations scattered throughout the treatment area. A reduction in survival of 84% can be attributed to the insecticide. Routine surveys of the spruce budworm infestation made annually by Maine Forestry Department personnel were used. The reduction of 84% in survival was not sufficient to alter the course of the infestation in the treated area, for a comparison of egg masses in the 1969 and 1970 surveys showed only a slight reduction in the treated area. Outside the treated area the epidemic budworm infestation expanded in size and intensity. The treatment was successful in preserving much current foliage, especially on those trees most severely damaged in recent years. The treated area was sufficiently improved in overall tree condition that treatment was not recommended for 1971.

Intensive monitoring of budworm populations on five heavily infested plots showed that when the prescribed dosage reached the target tree a substantial amount of current foliage is saved. The prescribed dosage did not effectively suppress populations but left sufficient survivors to produce generally heavy levels of new egg masses. The first application has the greatest impact on foliage protection with relatively little effect on population reduction. Whereas the second application has the greatest impact on population reduction with little effect on foliage protection. The data suggests that a higher dosage in the second application (5th instar) would provide better population control.

The broad spectrum of Accothion is evident from the knockdown of predaceous and parasitic arthropods, including spiders, and parasitic Diptera and Hymenoptera. Spruce budworm parasites killed, include Meteorus trachynotus and Glypta fumiferanae. The spiders and parasitic dipterans were not identified and may also contain species which attack budworm. There were no striking differences in the mortality of budworm larvae harboring parasites at the time of spraying.

Populations of stream invertebrates were monitored by bottom and/or drift sampling in six sprayed and six unsprayed streams. No reductions were detected in the variety of invertebrates collected. Total numbers collected were reduced somewhat, however. The reductions were statistically significant only for the Chironomidae, and these reductions appeared in all sprayed streams. Reductions in other taxa were restricted to one of the six sprayed streams, and it is suggested that this stream may have received an overdose of spray application. The impact of Accothion on aquatic invertebrates appear minor in comparison to some other pesticides, e.g. DDT.

Observations in the spray area were made on reactions to Accothion of a great variety of species of flora and fauna present. Accothion showed observable effects on some insects but not on other insects; nor on plants, birds, minnows in a confined pool, tadpoles, frogs, toads, and salamanders.

Two brooks located inside the spray area and one, serving as a control, located outside the spray area were studied to evaluate possible effects of Accothion upon fish life. No significant short-term changes in pre-spray and post-spray population estimates were evident. No mortality occurred in brook trout held in live cages throughout the study. Fish mortality at the site of blocking seines was high in one of the sprayed brooks and in the control brook. Most of this mortality is believed to have been caused by high flows coupled with spawning movements of many of the minnow species. The second application of Accothion may have contributed to a high mortality of common shiners. Samples of brook trout, white suckers, common shiners, creek chubs, and redbelly dace, will be analyzed for pesticide residues.

Pre- and post-spray bird censuses were conducted in both the spray and control area. Evening grosbeaks were apparently attracted to the budworm infestation area as 196 were recorded in the spray area as compared to 38 in the control area. An intensive carcass search covering an estimated 90 linear miles of tote road within the spray area disclosed no bird mammal or amphibian mortality or signs of aberrant behavior. One dead parula warbler was found in the spray area. A very depressed brain cholinesterase value strongly suggested that death was caused by Accothion. Two applications of Accothion

at a rate of two ounces per acre did not cause significant bird, mammal or amphibian mortality.

Free-flying sapsuckers were used to monitor the effects of Accothion on bird mortality and behavior. Observations of 74 birds were made, before and after spraying, at nine nesting territories in the sprayed area and at four in the unsprayed area. Sapsucker nestlings were banded and placed in nest-blocks, where normal nesting activities continued. Nestlings fledged and lived normally in their home territories. The spray apparently did not cause sapsucker mortality. Some mortality occurred but was probably caused by nest disturbance and predators.

Samples of grass forage, milk, and soil were chemically analyzed and showed the presence of Accothion up to 1.1 ppm. on grass, no presence in milk, and no presence in soil.

INTRODUCTION

In the fall of 1969 the Maine Forestry Department faced a damaging spruce budworm infestation on over 200,000 acres of spruce-fir forests in south central Aroostook County. The outbreak had been building over the past three years, the situation had been predicted. The budworm problem in the adjacent Canadian provinces was grim also. To the east in neighboring New Brunswick an infestation extended over nearly 3.4 million acres. To the north in Quebec, new infestations were expanding and covered nearly 50,000 acres. A careful evaluation of the biological and economic implications of the Maine outbreak showed that chemical control was the only acceptable alternative.

Recommendation for control action in 1970 was made by entomologists of the Maine Forestry Department. The recommendation was accepted by the Forest Commissioner, Land Managers and the U.S. Forest Service. Control action involved 210,000 acres centered in the Oxbow area of northern Maine (See map in Appendix).

With the phase out in 1967 of DDT for spruce budworm control, we were faced with need for a suitable substitute insecticide. Canadian research and large-scale operational control programs in neighboring New Brunswick, Canada indicated that the insecticide Accothion* at the rate of 1/8 pound per acre applied twice, was safe in the environment and provided acceptable control. The alternative chemicals were either unsuitable to Maine conditions or not available for use. Volumnious data gathered from studies in New Brunswick by Canadian forestry and other environmental agencies was submitted to the U.S. Department of Agriculture which resulted in granting of a temporary permit for use of Accothion in Maine. The control program was carried out in the period May 29 - June 15.

Knowing that this was the first wide scale use of Accothion in the United States, we made a concentrated effort to monitor it closely. Our objective was to determine the effects on the budworm and other life forms in the forest environment when Accothion was used under operational conditions. All but two of the environmental studies made in connection with the 1970 program are reported here. The field study on Accothion residues in the forest soil is not reported due to

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* Active Ingredient: O, O-dimethyl O-p-nitro-m-tolyl phosphorothioate

a failure in laboratory analytical procedures to identify the residues. A bioassy using brine shrimp was inconclusive due to insufficient replication in the experiment.

Project funding was arranged on an equal three-way basis. State funds were provided by Legislative action. The legislature also enacted a requested tax by and on all owners in the unorganized townships regardless of where they owned land (the so-called Maine Forestry District Tax). Federal funds were provided through the U.S. Forest Service under the provisions of the Forest Pest Control Act.

Planning and Application of the Insecticide

Robley Nash, State Entomologist

Maine Forestry Department, Augusta, Me.

Planning and Public Relations

Extensive planning and preparations took place for months in seeing that all was in complete readiness on the date spraying should start. Readiness is very important so as not to slight any activities and because both the season for budworm control as well as periods with air conditions suitable for spraying are short.

Discussion meetings were held with all agency representatives who were to be involved in the various environmental studies.

A 37-page set of control specifications described all that the spray plane contractor was to supply, his specific procedures, financial and operational responsibilities, and financial penalties in case of infractions.

Public meetings were held to explain full details of the needs, plans, and expectancies of the operation to conservation agencies and groups. These were followed up with similar meetings at Presque Isle just prior to the start of operations to explain procedures at the site. Explanatory articles of the same nature were given the news media.

Pre-spray personal contacts were made with all residents in or within one-quarter to one-half mile of the spray area. This was a repeat procedure of all previous operations. Purposes were (1) to explain all details of the operation and answer any questions and (2) to seek out dairy, poultry, mink, or bee farms, and fish ponds. Also sought out, were all high utility, radio, TV poles or towers. All were marked by erecting beacons and/or on U.S. G.S. maps. Owners of farms and ponds were given follow-up telephone notice just prior to spraying. At pre-spray briefing sessions guide navigators and spray pilots were supplied with these maps and told to shut-off spraying and not to turn over such

farms and ponds, as well as rivers, lakes, and streams. Maine and Federal Aviation Agencies and Loring Air Force Base advised us on avoiding conflicts with aircraft regulations and Air Force operations. Other precautions followed are given under the airport and Human Health sections.

Over-all planning and supervision of the project was by the State Entomologist and his staff. Personnel and assignments for the over-all operation are given in the organization chart on the following page.

The guessing game of setting the date for having materials ready and personnel on hand at Presque Isle at the right time to avoid adding to expenditures was met perfectly. Original estimates could be well made from previous experience with average spring development of the budworm and with past operations. Final date was pin-pointed more closely each day as May advanced from data supplied by field crews daily analyzing the instect's development

Airport Facilities and Mixing

As has been usual in large spray operations, the cooperation of other divisions of the Maine Forestry Department and many other agencies was extremely helpful. The Northern Maine Vocational Technical Institute provided meals and a domitory for housing those involved with the spray application. The State Department of Agriculture certified and sealed the meters involved in loading insecticide into the aircraft. United States Customs and Immigration and Maine State Police cooperated in moving of men and equipment from New Brunswick to Maine. The State of Maine Insurance Department cooperated in bond and insurance matters, Purchasing Office in authorizing hurriedly needed purchases, State Public Health Laboratories in safety matters.

The city of Presque Isle was helpful in various matters; the Maine Public Service Company set marker poles and the Aroostook Airways supplied various airport needs and map-room space.

During the week of May 11th, Maine Forestry Department Fire Control personnel installed cribbing for a large storage tank. On May 20th they set up the mixing and loading equipment and system together with a crew from Forest Protection Ltd. of New Brunswick by whom these items had been prepared and rented. Later they installed meters at three aircraft loading stations for accurate dispensing of the insecticide into spray planes, plus a water supply system from a nearby pond and holding tanks to insure a ready supply of water. Presque Isle city water was not used because it is chlorinated and therefore adverse to the stability of Accothion.

JUNE, 1970, AROOSTOOK COUNTY, MAINE, SPRUCE BUDWORM PROJECT, 210,000 ACRES, AND ACCOMPANYING SURVEYS.
BASE-Presque Isle Municipal Airport

OPERATED BY:
STATE OF MAINE
FOREST SERVICE
DIVISION OF ENTOMOLOGY

OPERATING FUNDS:
STATE, PRIVATE FEDERAL

COOPERATION BY:
1) U.S. FOREST SERVICE NORTHEASTERN AREA S.&P.F.
2) FOREST PROTECTION LTD. OF NEW BRUNSWICK
3) PRESQUE ISLE CITY MANAGER FIRE-POLICE DEPARTMENT
4) NORTHERN MAINE VOCATIONAL TECHNICAL INSTITUTE

Forest Commissioner
A. H. Wilkins

Deputy Commissioner
Fred Holt

Business Manager
William Cross

U.S. Forest Service Coordin.
John Chansler

Project Director
R. W. Nash, State Entomologist

Overall Budworm Reduction
Maine Forestry Department

Tech. Ass't
Trefts
Stark
(Ouellette)

Tech. Supervisor
John Coughlin

Collectors
Atwood
McMullen
McBreairty
Holmes
Breton
Pratt

Laboratory Analysis
B. Greenlaw M. Congdon
V. Robinson I. Currie
J. St.Peter M. Anderson
C. Morreault E. Gonya
V. Morris M. Sear
D. Martin

Accompanying Surveys For Dist. 3, 4, 5, and 6. Same Men Alternating

Efficacy Study of Accothion
U. S. For. Service
McCowan
Ford
White
6 helpers

Associated Monitoring
Maine Forestry Department

Terrestrial Insects	Dr. Brower
Aquatic Insects	Dr. Dimond & Malcolm
Me. Fish & Game	Bourque & Spencer
Me. Dept. Agric.	Johnson
Me. Dept. Health	Richardson & Epstein
Me. Sea & Shore	Hurst
U.S. Fish & Wildlife	Peterson, Gramlich & Fillmore
U.S. Forest Service	Rushmore

Pre-spray Contacts, residents. Trefts & Holmes

Radio Tech.
Cram & Staff

Communications and Weather Base Station - Presque Isle
J. Elliott and U.S. Weather Bureau

Sub-stations
Oxbow Road
W. Rafford
Ashland
R. Tucker

Airport Setup
Tingley

Activity Recorder
Marsh

Barracks Custodians
Townsend
York

Advice & Assist.
B. Flieger
B. McDougall
Forest Protection Limited

Maps & Progress
J. Walker
J. Hinkley

Airport Affairs, Calibration, Supply & Loading Clerk
Chadwick

General Safety & Caution Areas
Lipovsky

Handler's Safety & Condition
Richardson
Epstein

Pumps & Mixing
M. Bragdon-Leader
B. Downs
D. Hicks
R. Luce

Insecticide Loaders
A. Gibson
G. Michaud
H. Worcester

Airport Facilities and Gas Supply.
Aroostook Airways Inc.

2 Flag Planes
George Graham) Pointers
David Roberts)
Holmes Hansel) Pilots
Allyn Caruso)
B. Cunningham -Mechanic

3 TBM Spray Planes
Jim Holland)
Wayne Hughes) Pilots
Wendell Reid)

Plane Advisors
Wright & Robinson

Cooks
Mrs. M. Keagan
Mrs. J. Sawyer
Mrs. F. Fitzgerald

Spray Contractor*
Supervisor -
Jerry Wilson

Chief Mechanic -
B.J. Smith,
Assistants & Refueling -
Allan Fox
Gale Wilson
Terry Bateman

*Hillcrest Aircraft Company
Lewiston, Idaho

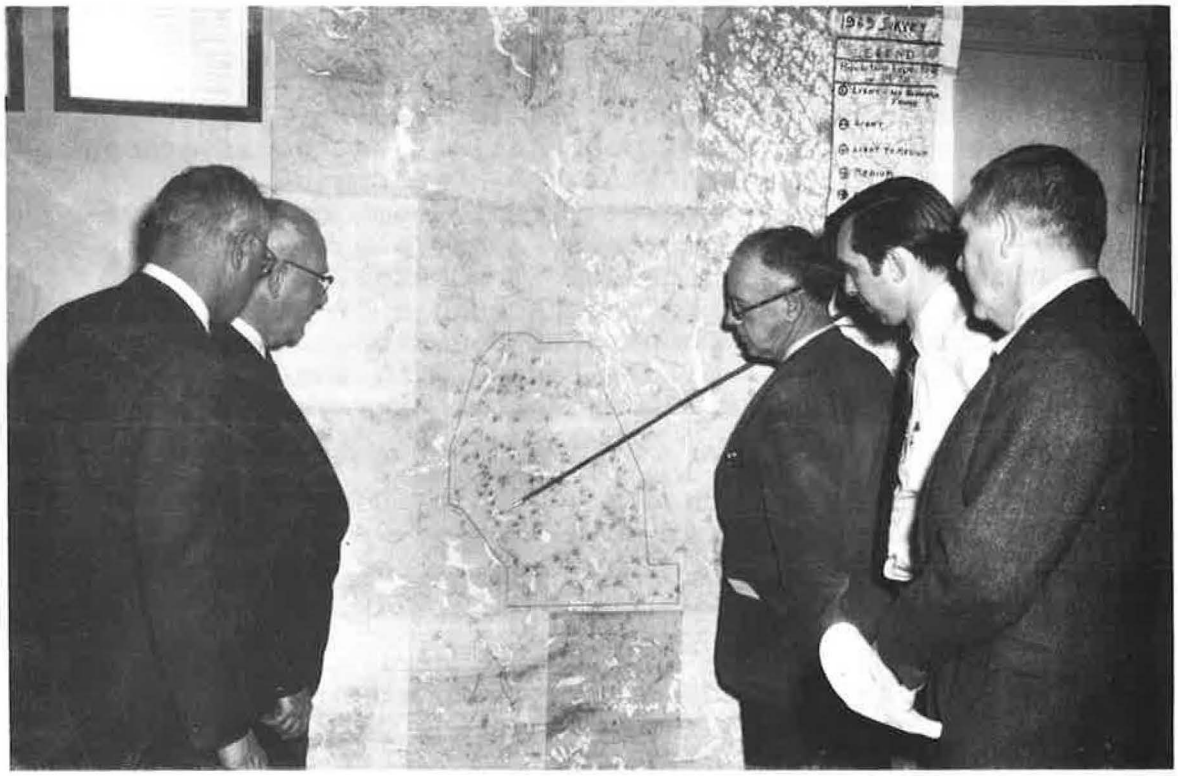
All others assigned to the airport arrived May 27th. Together they completed final preparations on the afternoon of May 29, including installation by Department radio technicians of the all-important radio communication system between airport headquarters, spray planes, flag (or guide) planes, and ground crews. The three TBM spray planes and pilots were obtained through a 37-page contract with Hillcrest Aircraft Company of Lewiston, Idaho. Two Cessna 172 aircraft and pilots for guiding the spray planes were contracted from Bar Harbor Airways, Ellsworth, Maine.

Spray planes were dispatched May 28th to Dunphy Airstrip, New Brunswick, for calibration by Forest Protection Ltd. at their headquarters since they had all previous operational experience in recent years with the insecticide.

On May 28th and 29th, the insecticide arrived in 48.8 gallon drum lots. It was immediately placed in a roped-off storage area marked, "No Trespassing" and provided with the 24-hour police protection in effect for all airport facilities throughout the operation.

Mixing and loading crews were thoroughly briefed beforehand in handling the insecticide as described in the section on Human Health. Gasoline was brought to the spray planes by truck for refueling when reloading with insecticide. Fire extinguishers were provided around all pumps and planes and a manned city fire truck was present during actual operations.

The insecticide Accothion emulsifiable concentrate was known as 8EC because each gallon contained 8 pounds of actual Accothion. Mixing involved 10.4 gallons 8EC with enough water to make 100 gallons of water emulsion. Each batch of water emulsion was mixed fresh just before loading into planes for application. A batch of 1875 gallons of emulsion required for each 3-plane load involved transferring 195 gallons of 8EC (4 drums of 48.8 gallons each) to a measuring tank on top of the mixing tank. A seperate pump was provided for this and the measuring tank had an outside gauge. At the same time 1680 gallons of water was pumped and metered into the mixing tank. Just prior to loading the planes, a valve at the base of the measuring tank was opened to allow the concentrate to flow down into the mixing tank to the water. A line from the pump used to load the aircraft led back to the mixing tank to provide agitation and mixing of the 8EC and water for a few minutes, then the line was opened to pump the mixture



State of Maine forestry officials brief USDA and USDI representatives on the proposed 1970 suppression project (fall, 1969)

State and federal officials planning a strategy to monitor the effects of Accothion on the forest environment.

directly into the spray planes. The lines to the planes were fitted with 2-inch Buckeye "Dry-break" couplings (two to each plane) to eliminate drippings when planes were loaded and couplings disconnected.

Application Rates

Two applications of Accothion were planned, timed to coincide with certain instar development in the life of the spruce budworm caterpillars. Requirements under Temporary Permit No. 241-Exp-50G issued by the Federal Government for the project called for the first application to begin when larval development had reached the peak of the third instar, the second application after development had reached the peak of the fourth instar.

As May advanced, development of the budworm catepillars was continually followed by the Maine Forestry Department's Portage laboratory (Details are given in Coughlin's report on this laboratory's work.) The peak of the third instar was reached on May 29th. Spray application began that evening. The first application was completed on June 7th and one load was applied to start the second application. The peak of the fourth instar had passed by that date. The second application was completed on June 15th. (See Coughlin's report, Figure 1).

The application rate of 2 ounces of actual Accothion in 0.15 gallons of emulsion per acre was achieved by the three spray planes each having 625 gallons per load, or a total of 1875 gallons. This team load was applied to a spray block of 12, 500 acres.

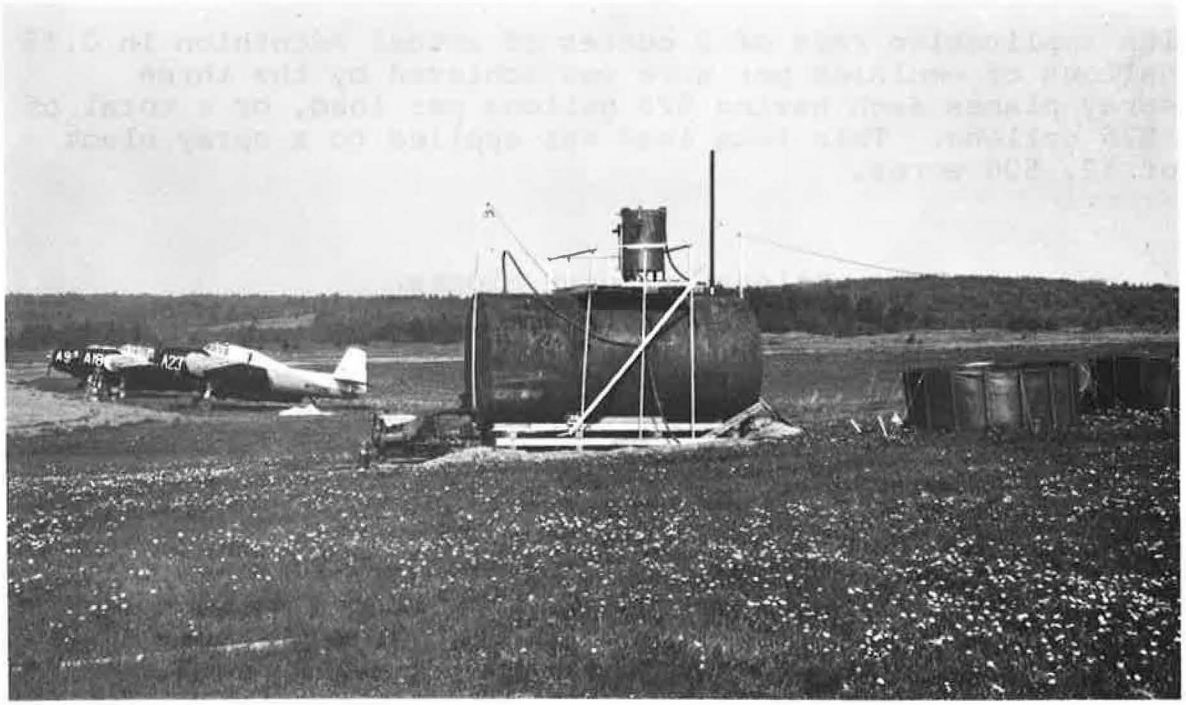
Releasing Spray Blocks

Decisions to spray and method of controlling the spray planes were through the mobile flag-plane system devised by Forest Protection Ltd. For the one team of spray planes, two flag (Cessna) planes were used each carrying an experienced navigator, one of which was assigned responsibility as chief.

Weather reports radioed to the air base from department of weather or fire lookout stations in the area started before daybreak and continued every half hour until spraying stopped. Reports started again in the evening as soon as

AUTHORIZED

Project direction and communications were centralized at the Presque Isle Airport. Police protection was provided by the City of Presque Isle.



Insecticide mixing plant and TBM aircraft at Presque Isle Airport.

winds showed any sign of being sufficiently low in velocity. Reports gave wind direction and velocity, temperature, dew point, and relative humidity, fog conditions, haze and possibility of rain. Navigators flying over the area checked low altitude conditions and with the weather reports radioed to them made their calculations. The chief then gave the decision to spray or not to. Likewise, the navigators made the decision when conditions demanded spraying stop. At times, the spray pilots with their experience were of help in radioing their observations. The U. S. Weather Bureau at Caribou and Loring Air Force Base gave good help in our planning by giving advance forecasts as well as precautions on when to expect shower activity.

Spraying was done more often from daybreak to 7 a.m., less often in the evening because winds did not subside in time to operate. However, evening spraying is acceptable because once winds drop and low air turbulence subsides to the point where spraying can start, conditions improve to the better.

In the mobile system of controlling spray planes, basic guidance was from the navigators in the flag-planes. Navigators established each line and course to be flown according to prepared maps and the terrain. Flight altitude was roughly 700 feet for the flag planes. Spray planes flew at 100-150 feet as a team of three with the lead plane lined up on, and following the two flag planes. The second and third spray planes were 440 feet to one side and behind the lead and second planes respectively. Radio communications allowed navigators to tell spray pilots of needed course corrections, when to turn spray on or off, and when to turn to spray return lines of the block being treated. Spray blocks were approximately 3 miles by 6½ miles (12,500 acres) and were usually laid out with, and always flown on, the long axis north-south. Spraying proceeded back and forth until the block was completed with twelve passes or swaths by the three planes to complete a block.

Effects of Accothion on Human Health

Ernest M. Richardson, State Chemist, Pesticides

Maine Department of Health and Welfare, Augusta, Me.

Objectives

The State Public Health Laboratory assisted the Maine Forestry Department in monitoring the health aspect of exposure of personnel to Accothion. State Chemist, Ernest Richardson was assigned as Health Officer and as the informal assistant to the Safety Officer. In addition to human monitoring of exposure to insecticide, it was his responsibility to supervise any necessary decontamination and to act as liaison with Gould Memorial Hospital in preparation for any poisoning emergency.

Cholinesterase Monitoring Study

Twelve men who were to work constantly in the restricted area were monitored for cholinesterase enzyme inhibition, which is the physiological indicator of exposure to an organo-phosphate compound such as Accothion. These men included mixers, loaders, pump operators, area supervisor, radio dispatcher, one plane mechanic, safety officer, and health officer. A plasma cholinesterase base line was established for each man prior to arrival of the insecticide concentrate. A second test was run after one full week of spraying and a third and final test conducted after completion of the entire project.

Blood was drawn at Gould Memorial Hospital at a cost to the project of $1.00 per sample. Analysis for cholinesterase activity was done by the Health Officer in a field laboratory set up near the airport. The data collectively showed no detectable change in enzyme activity due to exposure. No deviation was seen that could be attributed to anything other than normal daily variation in cholinesterase activity. The data of the study is shown in Table No. 1.

Table 1

Cholinesterase Activity of Project Personnel Working with the Organo-Phosphate Insecticide Accothion

Name	Project Job	Plasma Cholinesterase Activity pH. Units		
		Base line	First check	Final test
Manley Bragdan	Pump Operator	1.021	1.341	1.410
Richard Luce	Pump Operator	1.172	1.210	1.372
Bruce Downs	Mixer	1.055	1.377	1.568
Donald Hicks	Mixer	1.188	1.370	1.353
Albert Gibson	Loader	1.320	1.210	1.300
Harold Woorston	Loader	0.952	1.113	1.142
Gillie Michaud	Loader	0.568	0.705	0.685
Alan Fox	Plane Mechanic	0.833	0.945	*
James Elliott	Radio Dispatcher	1.093	1.145	1.368
John Chadwick	Airport Supervisor	0.755	0.900	*
Louis Lipovski	Safety Officer	1.017	1.018	*
Ernest Richardson	Health Officer	0.831	0.951	1.035

* Absent from final test

Personal Protection

On the site at the airport, the personal health of the men working with the insecticide was overseen by the health officer and/or the project safety officer.

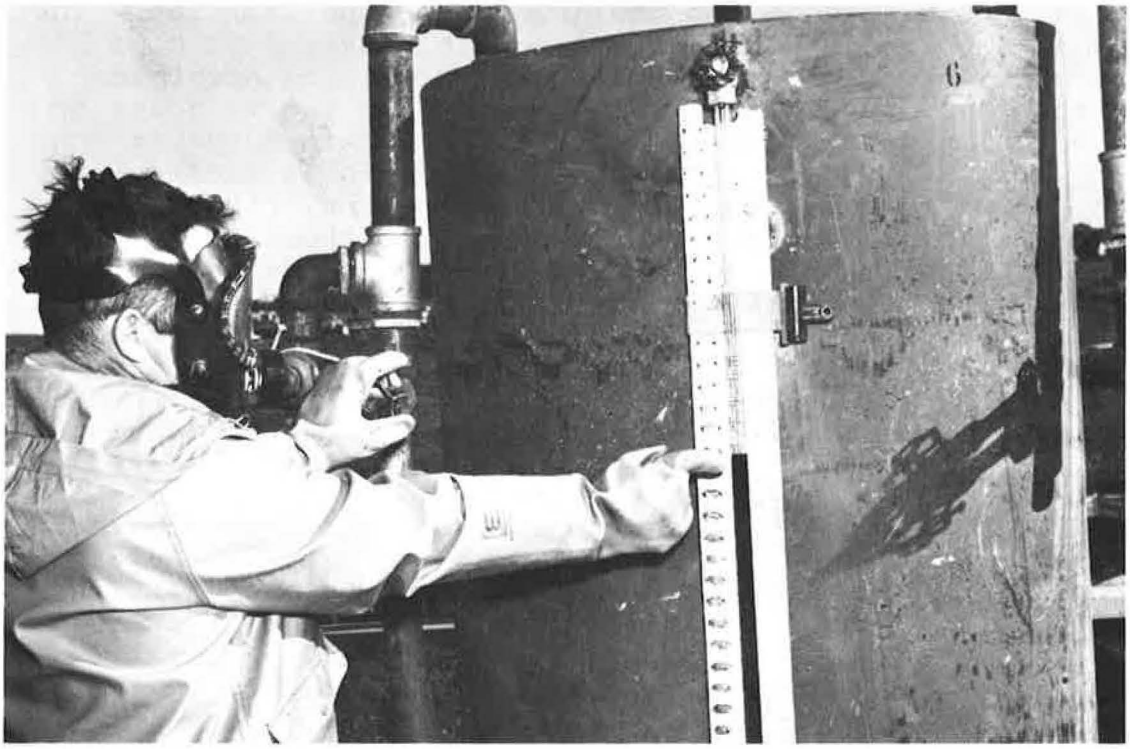
Clothing: All personnel working in the restricted area were required to wear rubber protective clothing, to include rubber rain suit, gloves, boots, and a full-face respirator. Items were purchased for the men locally. Reasons for full rubber dress were twofold; first, to prevent dermal absorption of the insecticide and secondly, to avoid ruining personal clothing in the event that a spill required decontamination, the chemical mixture for which is quite caustic and would destroy clothing and shoes.

Emergency Medical Backup Support: As part of the overall safety precautions in the handling of organo-phosphate poisons, arrangements were made to have the necessary antidotes on hand at Gould Memorial Hospital in Presque Isle. These chemical antidotes included atropine sulfate (a common hospital item), and 2-pralidoxime iodide (2-PAM or Protopam), purchased by the hospital from Ayerst Laboratories, New York, N.Y. The hospital staff was briefed verbally on the diagnosis and treatment of organo-phosphate poisoning and the staff and emergency team were shown a medically oriented film on the same subject. The orientation resulted in a medical team prepared to handle phosphate poisoning emergencies.

Modification to Canadian Apparatus: It was found that the Canadian mixing tank gave off a considerable amount of strong fumes of Accothion during the mixing process. These fumes were coming from the 24 inch top viewing port and from a 4-inch vent at one end of the tank. It was felt that exposure to these fumes was dangerous and put the mixer in a needlessly hazardous condition regardless of his protective clothing and respirator. The top viewing hole was thus sealed with a lid and rubber gasket (truck inner tube) and a 4-inch by 10-foot extension of iron pipe was made into the 4-inch vent at the end of the tank. These precautions completely eliminated the fume hazard to the mixer and surrounding ground personnel.

Decontamination Procedures

Personal: It was necessary to provide facilities for personal decontamination in the event of a spill and for



Personnel working in the insecticide restricted area were required to wear rubber rain suits, gloves, boots, and a full face respirator.

decontamination of gloves and boots after each man finished work in the loading pit or concentrate storage area. Two 30 gallon trash cans were purchased for this purpose, one being placed directly adjacent to the concentrate storage area and one centrally located on the loading flight line. Each was equipped with a long handle brush and filled with decontamination solution consisting of two pounds of washing soda, two quarts of chlorox bleach, and one half cup of liquid detergent concentrate (Joy).

Spills: Accidental spillage either on the runway during loading or in the concentrate storage area was decontaminated immediately using the washing soda-bleach-detergent mixture from the decontamination stations mentioned above. Ten-quart pailfuls of the decontaminant were poured onto the spill and the solution scrubbed into the contaminated area with the long handled brushes. Only three minor spills occurred, which offered no problem.

Drum Decontamination: Each 55 gallon Accothion drum contained about one pint of concentrate after the pumping and draining process was complete. Decontamination was performed after draining by the addition of one pound of washing soda, 2 quarts of Chlorox bleach, ¼ cup of Joy detergent and 10 gallons of water. The bung was then replaced and tightened and the drum turned on its side. The drum was rolled and agitated frequently over a 12 hour period to break down chemically any remaining Accothion on the inner surfaces of the drum. After twelve hours or more the bung was removed and the drum drained into a dug sump hole. The drum was then set aside for a final rinse. When about forty drums were awaiting a final rinse, each drum was inverted and set on another and thoroughly rinsed with copious amounts of water under 200 pounds pressure from booster lines of the duty fire truck. After draining, the container was turned right side up, the bung replaced and its exterior also thoroughly washed with this high pressure water stream. At this point the Accothion concentrate drum was considered adequately clean and decontaminated.

Lye is the strongest decontaminant for organo-phosphates. However, its use is hazardous due to its extreme caustic properties. In that Accothion falls in the "slightly toxic" category according to comparative dermal and oral LD-50 values for rats in a publication by Arthur Gall, Maine's Extension Specialist in Pesticide Safety, it was decided that a washing soda-bleach-detergent mixture would be safer to handle and dispose of, and yet do an adequate job of decontamination.

Conclusions and Recommendation

Data from the human monitoring program showed that with the precautions of special clothing, respirators, and decontamination taken as part of the overall safety program, there was no exposure of personnel to the organo-phosphate severe enough to show any decrease in plasma cholinesterase activity over and above normal daily variation. Healthwise, with regards to exposure to Accothion, each member of the team left the project in as good health as when the project was initiated.

It is felt by this pesticide analyst that if the same type of project is initiated again, a different arrangement should be made for disposal of drums. Decontamination of these drums was easy and considered complete. However, as a result of the decontamination process there was large amounts of foul looking material being poured into an earthern sump to be absorbed into the earth in due time. Had this dumping of the decontaminant been viewed by the onlooking public, there could have been some serious concern and adverse publicity. It is hereby recommended that in the future, drums not be decontaminated at the site, but rather as part of a purchase contract of the insecticide, that the company agree to take back the empty drums. In this way the airport facility and any groundwater or surface drainage nearby would not be contaminated with foreign chemicals in the form of either the toxic or detoxified insecticide or decontaminating agents.

Effects of Accothion on the Spruce Budworm (Over-all Project Effectiveness)

John Coughlin, Entomologist
Maine Forestry Department, Augusta, Me.

Objectives

Entomologists of the Maine Forestry Department undertook several obligations in connection with the 1970 spruce budworm project: 1. To follow the seasonal development of the insect in order to time the various surveys and the spray treatment itself. 2. To determine the effectiveness of Accothion in controlling the insect population and protecting the foliage. 3. To follow the course of the infestation throughout the threatened area. 4. To provide experienced laboratory staff and facilities for studies by U. S. Forest Service personnel (described elsewhere). Since the 1970 work was only a part of a program of annual assessment and surveys of the spruce budworm by the Maine Forestry Department, a considerable reservior of experience and facilities was available. Similar work goes on every year and is expected to continue as long as the problem continues.

Methods

To follow the development of the insect, a location well within the treatment area was chosen for accessability and high insect population. On 13 May and every day or two thereafter foliage was collected from the mid-crown of fir trees at this point and brought to the Portage Laboratory. Technicians at the laboratory removed the budworm from the foliage,classified their development, and plotted the results. Other survey collections coming into the laboratory were compared with those plotted to be sure that the point chosen to follow development was representative of the general area to be treated.

As the time for treatment approached, another location, just outside the treatment area, was also followed for development. After treatment started, development in the treated area was retarded and erratic and most information then came from just outside the spray area. Development of the spruce budworm in the Oxbow-Masardis area is outlined in Figure 1.

To determine the effectiveness of the insecticide in controlling the insect, a series of before and after foliage collections were made. Prior to the start of the field season, 125 locations within the treated area and 193 locations outside were listed. Within the treatment area these locations were along existing trails and woods roads well scattered throughout the entire area. Field crews were sent to as many locations as time permitted prior to treatment.

At each point, five 15-inch long branches were taken from the mid-crown of each of five co-dominant fir* trees using sectional aluminum pole pruners with cloth bags attached just below the cutting head. All 25 branches, bundled in groups of 5, by tree, were placed in a plastic bag and taken to the laboratory. The collection site was assigned a number, plotted on maps, and the 5 sample trees marked with plastic flagging to facilitate re-sampling. At the laboratory, locally hired and trained workers examined each sample branch by branch and recorded the larvae found.

When the insecticide treatment started, field crews were shifted outside the treatment area and made identical collections, working from prepared lists of locations and working out from the periphery of the treatment area. Within the treatment area, a number of 6x6 cloth drop sheets were placed to facilitate observations of spray effect. Two locations were selected and 3 sheets were placed at each location, approximately 2 chains apart along a line perpendicular to spray plane flight lines. These drop sheets were similar to and supplemented similar projects by other agencies.

Following the completion of the spray operation, as many as possible of the pre-spray sample locations were revisited. Normally, the same crew visited each location and sampled the marked trees as before. At the laboratory the samples were examined and results compared with the pre-spray samples.

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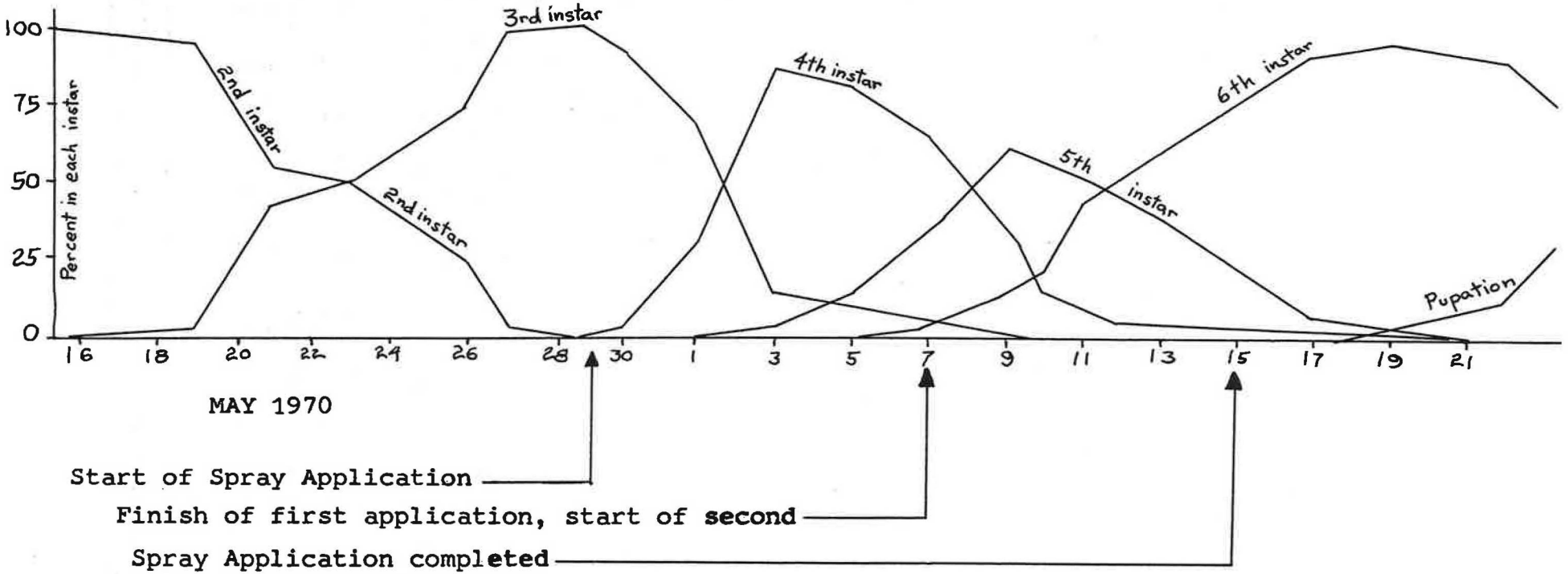
* Red Spruce was sampled instead of fir at four locations. The data were not considered separately but added to the fir samples.

FIGURE 1. DEVELOPMENT OF SPRUCE BUDWORM IN 1970 (DATA FROM OXBOW AND MASARDIS)



Beginning in August, a third survey was made, visiting all listed locations within and outside the treated area and many unlisted locations as well. As before, five 15-inch long branches from each of five co-dominant trees were brought from each location to the laboratory. This third survey sampled the egg masses laid by the 1970 spruce budworm adults and indicated the locations where larval feeding will occur in 1971. These data were plotted on maps and compared with 1969 data to indicate the course of the infestation from one generation to the next.

As soon as budworm feeding was completed, aerial observations were made to record defoliation. Later, in August during the egg mass survey, field crews noted and recorded defoliation at each sample point. Current (1970) defoliation, previous defoliation, and estimates of tree recovery were all recorded and later plotted on maps. A "hazard rating" for each location was then calculated considering the above three factors and the chance for further damage indicated by the egg mass numbers.

Results

A total of 86 before and after "paired" collections were made within the treated area. (Figure 2) Outside the treated area a similar series of 25 before and after paired collections were made.

Grouping all 86 collections within the treatment area, a total of 34,260 larvae were found in the pre-spray samples. The same trees sampled after spraying yielded 3125 surviving larvae and pupae. Similarly, outside the treatment area 3186 larvae were found in the first series of collections; 1840 were found later on the same trees. Comparing the survival in treated areas with that outside, a reduction in survival of 84.2% can be attributed to the Accothion application (Table 1).

Other effects of the insecticide were noted on the morning of treatment and two days later by observing budworm and other insects on the drop sheets and in the general vicinity. On the morning the area was treated, numerous budworm larvae could be seen hanging by silken threads and dropping to earth. Examination of foliage revealed both sluggish disoriented larvae and others apparently still healthy. On the drop sheets were many dead and dying larvae as well as some apparently healthy specimens. Two days after the second spray application, a re-examination of the drop sheets indicated many dead and dying budworm

FIGURE 2.

LOCATION OF PRE- AND POST-SPRAY SAMPLES IN THE TREATED AREA (Maine Forestry Dept. Data)

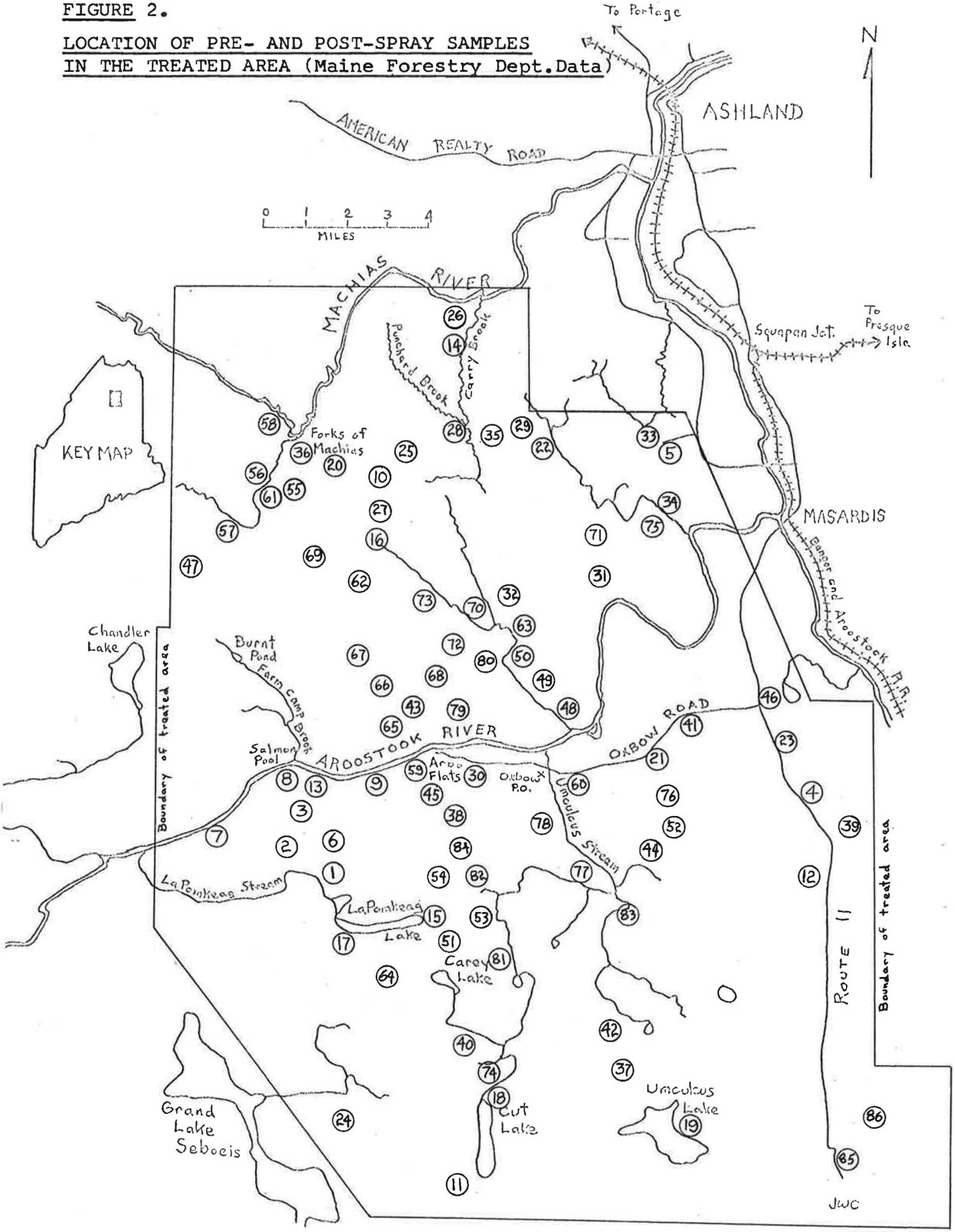


TABLE I

SUMMARY OF 1970 ACCOTHION TREATMENT
AGAINST SPRUCE BUDWORM

	TREATED AREA (86 LOCATIONS)	UNTREATED AREA (25 LOCATIONS)
Total Budworm before treatment	34,260	3,186
Total Surviving budworm after treatment	3,125	1,840
Survival	.091	.577

Percent reduction in survival by spraying $= \frac{.577 - .091}{.577} \times 100 = 84.2\%$

as well as other insects. Many live budworm collected from the drop sheets subsequently died. While the drop sheets gave no quantative data, they provided good sites for general qualitative observations.

observations of defoliation from the air and from the ground are combined in Figure 3. A feature of the 1970 defoliation was the total lack of any discernable pattern. The area involved is far from uniform with hardwood ridges, cutting operations going on presently and in the past, and old burns. In general, while there was heavy current defoliation over extensive areas, the areas that were in the worst condition in 1969 seemed to be the most improved in 1970. It was generally believed that the more open foliage of severely injured trees allowed greater penetration of the insecticide. It was also observed that generally the tops of the trees experienced the greatest improvement. Throughout the area it was observed that the forest was in generally improved condition and that there was much new foliage in 1970. This is in general agreement with Canadian experience where protection of current year's foliage is a major goal.

Surveys during the larval period, the aerial survey for defoliation, and the egg mass survey all showed an enlargement of the infestation during the 1970 season. Not only is the defoliated area larger than shown in Figure 3, but a new epicenter seems to have arisen in the Cross Lake-Madawaska Lake area northwest of Caribou. (Figure 4).

Collections of fir foliage from 105 locations within the treatment area and 218 locations outside the area were examined during the egg mass survey. Egg mass numbers within the treated area decreased slightly from an average of 1.440 per 15-inch fir sample tip in 1969 to an average of 1.245 in 1970. Outside the treated area, egg mass numbers more than doubled from an average of .171 per 15-inch fir sample tip in 1969 to an average of .400 in 1970.

The proximity of these infestations to the Canadian border should be noted since extensive and expanding infestations were noted in both Quebec and New Brunswick and Maine is geographically and biologically part of the continuing budworm problem throughout this area.

Discussion

It would appear that the 1970 treatment with Accothion was successful in keeping the infestation from becoming worse in the treated area. Control of the order of 84%, while

FIGURE 3. DEFOLIATION IN THE TREATED AREA, 1970

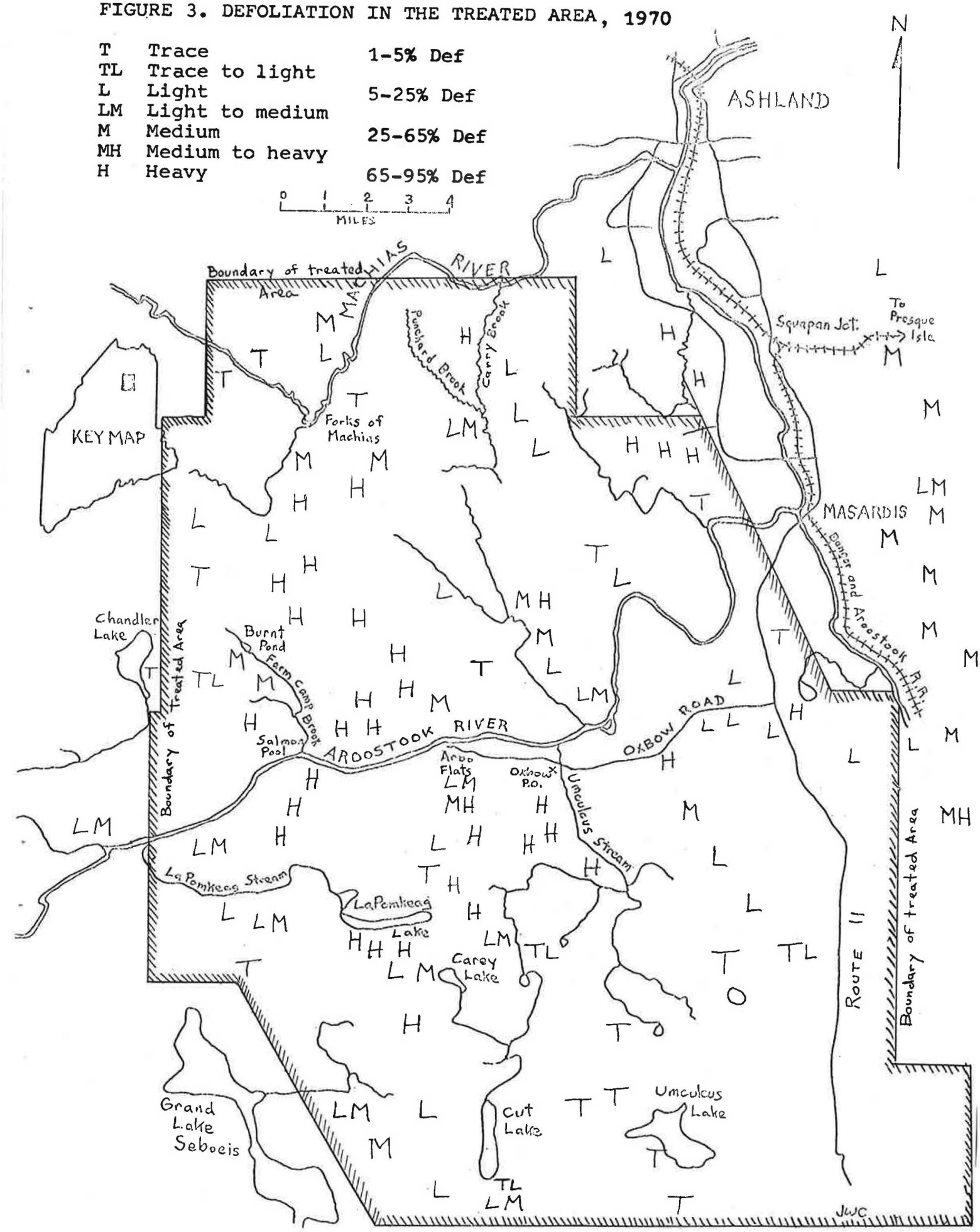
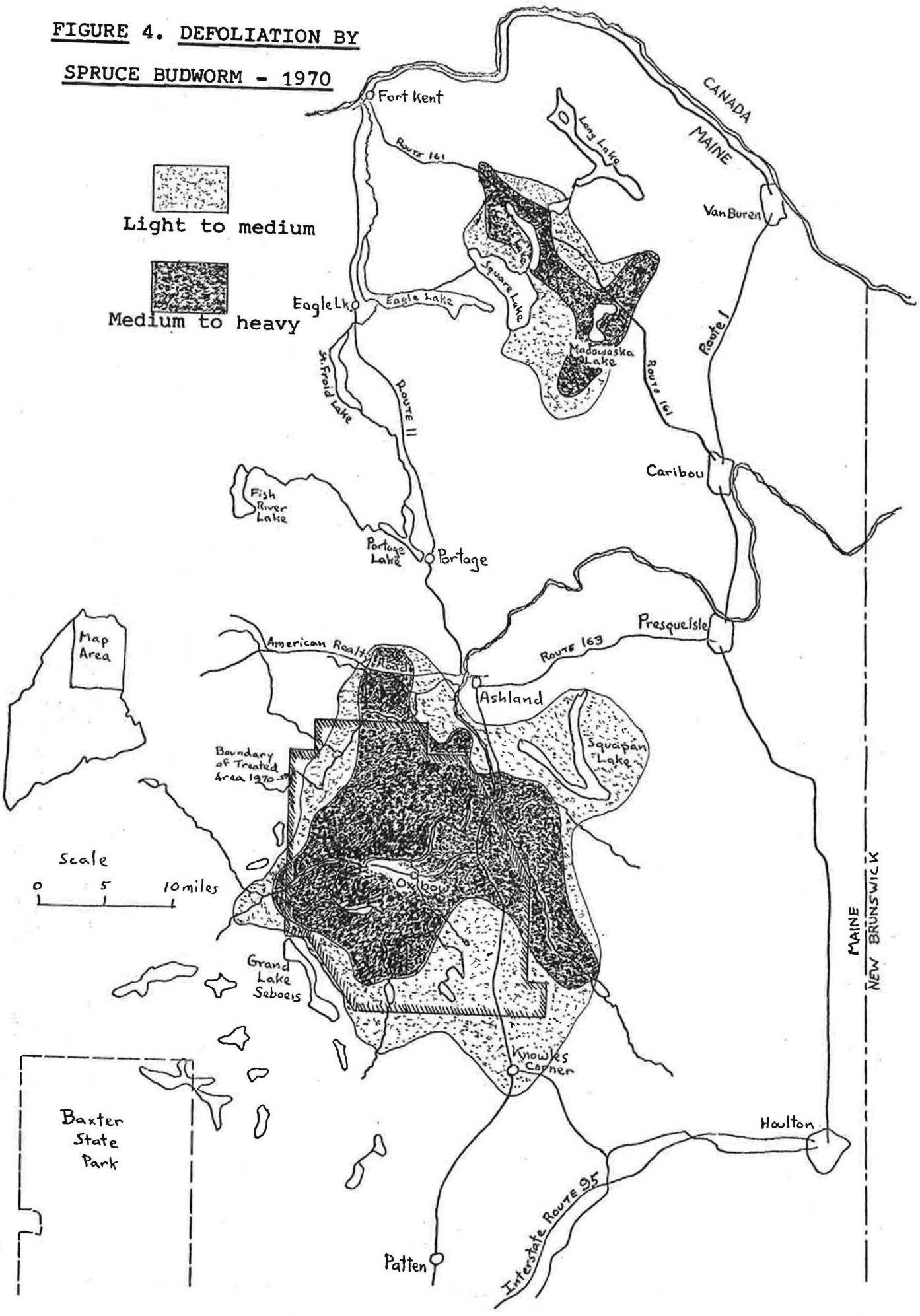


FIGURE 4. DEFOLIATION BY SPRUCE BUDWORM - 1970



far short of the degree needed to reduce the spruce budworm population, did seem to be sufficient to prevent increase. While it is unfortunate that experience and methodology do not permit accurate measurements of foliage protection, there was agreement among the experienced personnel present that a high degree of foliage protection had indeed been achieved - so much so that later recommendations were that no budworm control be undertaken for 1971.

Another year's damage from further budworm feeding appears to be tolerable, especially since the 1970 insecticide application gave some relief to the most severely affected trees. The 1971 damage is expected to be severe and action would seem to be needed the following year to prevent widespread mortality.

The problem is clearly becoming worse, for the Oxbow infestation enlarged considerably and the new epicenter arose northwest of Caribou. With present technology it would appear necessary that emphasis be shifted from population reduction to foliage protection as needed, with the overall goal of keeping the trees alive. This would be directly in accord with experience in nearby New Brunswick where the same methods and insecticide have had several years of use.

Conclusions and Recommendations

It appears to be entirely possible to keep the forest alive with the material and methods used in 1970. The lack of any high degree of population reduction indicates that more frequent treatment will be necessary to achieve this goal than was formerly necessary with DDT in Maine. Since the problem and its treatment are now so closely in accord between Maine and New Brunswick, it is desirable that even closer relationships exist in the future. A better or more effective material than Accothion would be desirable but until or unless one becomes available it is clearly desirable to refine the use of this material hoping for not only foliage protection but population reduction as well.

Effects of Accothion on the Spruce Budworm (Intensive Investigations on Small Plots)

John F. Chansler and John B. Dimond

Entomologists

U. S. Forest Service, Portsmouth, N. H.

and

University of Maine, Orono, Maine

Objectives

The objective of this work was to precisely measure the effectiveness of this insecticide in controlling the budworm. Three measurements of efficacy were taken: 1) The response of budworm populations to known amounts of spray deposit reaching infested trees or clumps of trees; 2) the amount of foliage protected from defoliation by known quantities of spray deposit; and 3) the infestation recovery rate as indicated by the egg population at the start of the first generation following spraying.

The techniques we chose to obtain these measurements closely resembled those used by the Maine Forestry Department (see Coughlin's report). A major difference was in the system we chose to select sampling points. Also our scheme for monitoring population control was extremely intensive by comparison. By using similar techniques we hoped to provide a better understanding of the over-all projects results as reported by Coughlin.

The planning and execution of this work were carried out by the U.S. Forest Service in cooperation with the University of Maine. The Maine Forestry Department provided field laboratory facilities and the personnel necessary to handle and examine the massive samples of foliage.

Methods

The intensive studies of spray deposition, budworm population reductions, foliage protection, and infestation recovery rate were carried out on five rectangular plots in the more heavily infested portions of the Accothion spray area (see map in Appendix). Maine Forestry Department data on expected budworm population levels were used to locate the five study plots where the insect would be particularly abundant.* One long side of each rectangular plot was located on a road, providing access, and all but plot IV were oriented so that the long axis of the plot was perpendicular to the flight lines of the spray planes. No more than one plot was located in any single 12,500 acre spray block.

Two additional study plots, outside the spray area, were chosen to serve as unsprayed controls. While these were substantially infested with the budworm, population levels were much lower than in the treated plots. Since the population levels between sprayed and unsprayed plots were not comparable, limited use was made of the data from the latter.

A sampling scheme of completely randomizing sample trees was considered but the forest type and other circumstances made such a scheme completely impractical. Instead, a system of sampling trees along a straight line was chosen.

Preparations of the plots involved marking and clearing a trail and selecting and marking study trees. The trail started at one corner of the rectangular plot at a point of access, proceeded in a straight line to the middle of the opposite long side, then returned diagonally across the plot to the other corner on the proximal long side. This produced 1½ miles of straight trail but with an angle at its mid point. Fifty balsam fir trees were selected as study trees along the trail and numbered 1-50; twenty spruce were similarly selected and numbered 51-70. Red spruce was selected most often, but where the species was unavailable black spruce or white spruce was used. The high mortality of fir in the interior of plot IV made it necessary to locate more than half of the study trees along a dirt access road that formed one long side of the plot.

Because of the patchy distribution of fir and spruce within the plots, study trees were not at all evenly spaced along the lines. Rather, most occurred in clumps of which two to several were selected and marked. The analysis of data was

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* Coughlin, J. 1969. The Spruce Budworm in Maine, 1969. Division of Entomology, Maine Forestry Department. Processed, 17 pages.

made on the basis of means of clumps of trees where the individual trees were sufficiently close together that the spray input was essentially uniform. Study trees separated from each other by longer distances were considered as a "clump" containing a single tree.

Criteria for selecting study trees were an open crown and a size, 30-60 feet, allowing removal of mid-crown branch samples with a pole pruner. Since spray deposit cards were to be placed in the open on the ground beside each tree, it was usually necessary to remove vegetation on one side providing a direct opening to the sky.

The degree of opening available for card placement was rated for each tree as follows:

A - opening equivalent to removing several codominant trees; usually trees given an A rating were adjacent to roads or clearings.

B - opening equivalent to removing 1 or 2 codominant trees.

C - a direct opening to the sky existing, but considerably smaller than that produced by removing one codominant crown.

D - no direct opening to the sky.

The great majority of study trees were adjacent to A and B - rated openings, and no differences related to degree of opening were noted in the amount of spray reaching cards placed in these two types of situation. Spray readings on cards in C and D - rated openings were decidely below average, however, since much was intercepted by the interfering canopy above. Readings of spray deposit for tree clumps were made, therefore, by averaging the deposits only of the cards placed in the higher rated openings of that clump, as these best represented the spray dosage applied to that local area.

Cards used for spray assessment were 3 by 5 inches white, Chromecoat cardboard. Each was stapled at the corners to a slightly larger plywood sheet for exposure to the spray. Cards were placed on the plots immediately before treatment to avoid wetting from rain or dew, and were retrieved within an hour or two after treatment. Spray droplets were counted on 50 sq. cm., about two-thirds of the card, using a microscope, and the size distribution of samples of the droplets measured with an ocular micrometer. Conversion from number and size of droplets to amount of spray received per acre was done after calculating the size on cards of a series of droplets of known volume prepared in the Entomology

Department at the University of Maine. This was confirmed by colorimetric readings of the quantity of dyed spray eluted from aluminum plates exposed alongside deposit cards in the field. A more detailed description of the procedures used to calculate the actual amount of spray can be given by the junior author on request. The procedure was adopted from those used by Chemical Control Research Institute, Ottawa, Canada.

Measurements of spruce budworm populations (larvae and eggs) and defoliation on the study of trees were made with the sampling procedure long used by the Maine Forestry Department. This involved counting the numbers of the insects on five, 15-inch branch tips pruned from the mid-crowns of each study balsam fir. Two branch tips was the sample size established for spruce in an effort to reduce the large task of searching the pruned samples for the insects. Each study tree was sampled 4-5 days before the first application and about 10 days following the second application, the prespray and post-spray budworm population estimates respectively.

Two 5-tree clumps, selected at either end of each study plot, were sampled in early August to estimate the rate of egg mass deposition of the new budworm generation. This provided an evaluation of the infestation recovery rate.

Defoliation of the study trees was estimated in August at the time of the egg mass survey. Feeding of the target generation of the budworm was completed at that time. Estimates were made of the percentage of current needles removed from the shoots by budworm feeding. This was accomplished by viewing in detail several individual shoots against the sky from the ground and with a cursory general view of the remainder of the tree. With practice, an observer becomes adept at defoliation estimations, giving highly reproducible results, although they may differ slightly from those made by other observers. These remarks apply only to fir. Defoliation is much more difficult to estimate on spruce. The needles on the latter are closely appressed to the shoot presenting a poor profile against the sky. Because of lack of confidence in the estimates, spruce defoliation data are not used in this report.

The degree of defoliation of a tree is often not uniform within a crown. Unless there is an extremely heavy budworm population, removing all the current foliage of a tree, there is usually markedly heavier feeding in the upper half of the crown. Because of this and because spray effects may have increased the difference in defoliation between crown levels, separate records were made for both the upper and lower crown halves.

A one-quart sample of the mixed spray was taken at the airport from each load applied to the spray blocks containing the study plots. These samples were sent immediately to the Biochemistry Laboratories of the University of Maine for gas chromatographic analysis of the contents. This step was taken to provide assurance that the study plots were treated with the recommended concentration of Accothion.

Results

Spruce budworm populations were reasonably uniform on the five study plots located within the spray area. Total larvae from 70 trees per plot, fir and spruce, sampled prior to spray application ran from 2800 to 3200. The average number of prespray larvae per 15" twig on the five intensively sampled plots was 10.1 on the fir and 10.4 on the spruce. The average from 10 nearby sampling points used in the extensive survey by the Maine Forestry Department was 18.4 on fir. The rather large difference is a reflection of the two different schemes to select sample trees. These plots were probably representative of the more heavily infested portions of the total area sprayed.

Spray deposit, however, varied considerably within and between plots, leading to differing budworm population levels and defoliation levels after treatment. The full data for the study plots are voluminous and are not included in this report. Complete data are on file in the Entomology Department, University of Maine and may be seen on request. Summaries and relationships between variables from selected data will be used in this section to illustrate the conclusions drawn from the work.

A brief summary of data arranged by plot means or totals is presented in Table 1. The deposit of spray of 3 oz. listed for plot I is an estimate, not the direct measurment, made for the following reason. The chemical analysis of the spray mixture applied to that block in the first application determined it to contain 4.9 percent Accothion, about one half the recommended concentration (Appendix). While the counts of number of droplets on deposit cards suggested that the plot received a full two ounces of spray in the first application, this was reduced to one ounce, because of the half-strength spray applied. This added to the two ounce dosage recorded in the second treatment produced an estimated average total dosage of 3 oz./acre on that plot. Because of the use of a diluted spray concentration on the first application on plot I, adjusted estimates of spray deposit were used for all further analyses.

Table 1. Summary of Accothion efficacy data (fir only) arranged by plots.

	Prespray Population	Mean[1] spray deposit	Mean[2] defoliation		Postspray population	Survivors per twig	Percent[3] control
Plot I	2364	3 oz.	38	29	519	2.1	78
II	2723	4 oz.	36	28	267	1.1	90
III	2922	1+ oz.	47	47	409	1.6	86
IV	2567	4 oz.	31	41	190	.8	93
V	2155	2 oz.	71	78	1101	4.4	49
Control							
I	1250		50	--	1050	4.2	24
II	650		66	--	850	3.4	0

1/ Ounces of actual Accothion per acre; sum of two applications
2/ Estimate for upper crown (left) and lower (right) crown respectively.
3/ No adjustment for natural control

The spray deposit on plot III is listed as 1+ because of a recorded average of 1 oz./acre deposited in the first application, but with no record of the deposit in the second application, because of failure to place the deposit cards in the field in time before the treatment. Total deposit data are therefore not available, limiting use of the remaining data from that plot. We may presume, however, that unless the second treatment greatly exceeded the recommended 2 oz./acre, the plot received less than the recommended total dosage because the first application was low.

Plot V received poor coverage in both applications, totalling only half the recommended amount of Accothion. This plot was located, however, within one half mile of the spray area boundary where below average coverage can be expected. This study plot was established before it became necessary to drop the 12,500 acre spray block bounding on the north.

Plots II and IV received the recommended total dosage of Accothion, but in different ways. Plot IV received very uniform coverage of about 3 oz. in treatment 1 and 1 oz. in treatment 2. In plot II, coverage in both treatments was erratic. While it averaged 2 oz. in both applications, some tree clumps were missed in one or both treatments, and others overdosed. The great variability in dosages received by different clumps in plot II made these data very

Pole prunners with an attached basket were used to collect 15-inch twig samples from the upper mid-crown of fir and spruce trees.

Women examined the twig samples for spruce budworm. Eight women were stationed at the Portage Lake field laboratory and four were stationed at Cross Lake.

useful in one of the analyses of results described later.

Where the recommended dosage of Accothion was applied, plots II and IV, a decrease in budworm numbers of about 90 percent was achieved. This estimate of reduction has not been corrected for the amount of natural mortality occurring simultaneously, an estimate of which is usually taken from unsprayed control plots. In the present experiment, the control plots provided erratic results of natural budworm declines, one showing an increase in numbers. These are believed to provide a poor representation of events in the more heavily infested experimental plots. The extensive studies of Morris (1963)2/ suggest that we should expect a 40-50% natural decline in epidemic budworm populations within the period encompassed by our pre- and post-spray collections. Natural population reductions based on the extensively sampled plots averaged 42.3 percent. (See Coughlin's report).

Defoliation on plots II and IV averaged 31 and 36 percent in the upper crown. There are no data available to provide a comparison of the observed level of defoliation with what would be produced by similar levels of budworm populations in the absence of spraying. Previous experience suggests that the level would be 80-90 percent.

Statistical analysis of the data in Table 1 involved paired t tests of comparisons of means. Several of the variables, spray deposit and budworm population counts were transformed to the log 10 (x+1) form to attempt to stabilize mean-variance relationships. These transformations were maintained in all subsequent analyses. All statistical tests were made only at the 95% probability level.

The first spray application was significantly heavier in plot IV and significantly lower in plot II than in the other plots, the other three plots indistinguishable. In the second application, a significant difference was demonstrated only in plot II, which received the heaviest treatment. With the combined, total application as listed in Table 1, only plot IV was significantly different. Plot II data, while the average approached that of plot IV, were much more variable due to uneven application, explaining why a significant difference was not noted.

In the defoliation column, plot V showed the only significant difference between plots in defoliation in the upper crown. With lower crown defoliation, plots I and II were not significantly different from each other, nor were plots III and IV. All other differences reached levels of significance.

Among the survival data, plot V was different from the remaining plots and plot I was significantly higher than plot IV. In

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2/ Morris, R. F. 1963. Mem. 31, Ent. Soc. Canada, p. 19

percent control, only plot V could be demonstrated as significantly different.

Table 1 provides data only for the fir sample trees. Control of the budworm on spruce was considerably lower in each plot. The percent control figures for spruce were 71, 57, 71, 65, and 23 respectively for plots I-V.

Egg mass survey data for the five plots are presented in Table 2, together with a repeating of some material from Table 1 for comparative purposes. There is relatively little similarity between the degree of control on a specific plot in 1970 and the forecast for populations in 1971, except in the case of plot V, where control was poorest and egg mass counts highest by far. Since moth dispersal occurs during oviposition one would not necessarily expect a good fit on small plots. The infestation recovery rate was high; Table 1 shows that the small plots have a high budworm population again. Coughlin's extensive survey data also showed a high rate of infestation recovery. His ratio of post spray egg mass densities to pre spray densities was .865. However, in unsprayed areas the ratio was 2.355.

One may comment on the overall success of the 1970 Accothion project using the data presented in Tables 1 and 2, assuming that the five plots are representative of the total spray area. The goal of foliage protection was apparently reached satisfactorily. Defoliation on those plots adequately treated was reduced to 30-40 percent from an expected 80-90 percent. Defoliation of the former level can probably be tolerated by fir trees for many years without tree mortality.

The other goal, budworm population reduction, was not satisfactorily realized. With budworm population reductions reaching no higher than 93 percent at best, there were sufficient survivors to produce generally heavy levels of egg masses. Such a situation resembles agricultural pest control where, in spite of heavy kill of insects every year and achieving a goal of product protection, the insect populations remain perpetually in outbreak. This result, up to the present, has generally been considered unacceptable in forest insect control in the United States.

Functional Relationships Between the Measured Variables

The greatest benefit, perhaps, from the data collected in the present study are derived from examining functional relationships between the variables studied, e.g. between spray dosage received by a tree clump and the resulting mortality or the resulting degree of defoliation. This allows prediction of effects to be expected if dosages greater or lesser than 4 oz. of Accothion/acre were to be applied. Evidence of this type

is not provided by the simple summation of data, as in Table 1.

Simple regression analyses, using some variables transformed as discussed earlier, were run between all possible pairs of variables as listed in Table 1 and separately for each plot. Least square regression lines were calculated, with 95% confidence limits, and with t tests used to determine significant relationships and for differences between slopes when the different plots were compared.

Table 2. Egg mass collections on balsam fir from experimental plots following Accothion application, with comparative data on budworm control

	Egg masses/25 twigs 1/	Expected populations 1971	Survivors/twig 1970	Postspray larval population
Plot I	33	Medium-Heavy	2.1	519
II	39	Heavy	1.1	267
III	26	Medium-Heavy	1.6	409
IV	45	Heavy	.8	190
V	108	Heavy	4.4	1101
Control I	49	Heavy	4.2	1050
II	9	Light-Medium	3.4	850

1/ Mean of two samples

The results of these analyses can be summarized briefly. The dosage of Accothion in the first application was significantly related to degree of control and to defoliation on at least some of the plots, particularly plots I, II and V. The relationship between deposit in the first application and number of budworm survivors is presented in Figure 1, and between that application and defoliation, upper crown, in Figure 2. This spray application appeared, therefore, to influence both objectives of the spray, foliage preservation and budworm population reduction; evidence is presented later suggesting the greatest effect on foliage preservation.

The Accothion deposits in the second application showed significant regression relationships only with survival data, as shown in Figure 3, and not with defoliation estimates. This suggests that the importance of the second application was in

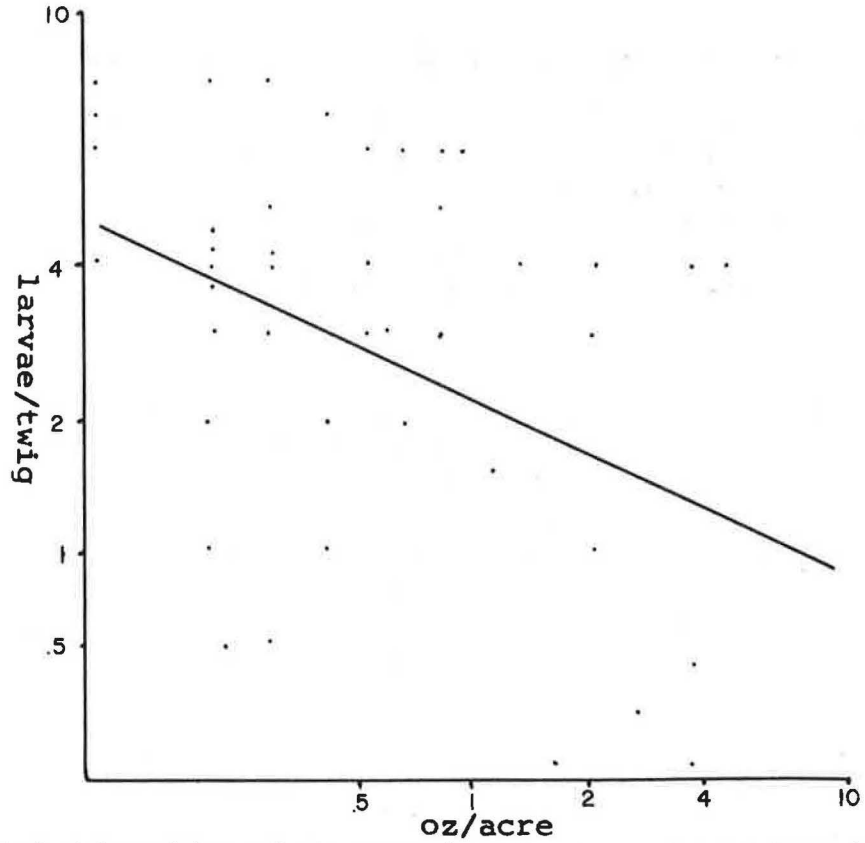

FIGURE 1. Relationship of dosage in first application (X) to numbers of spruce budworm survivors (Y). r= -.44 Plots I and V.

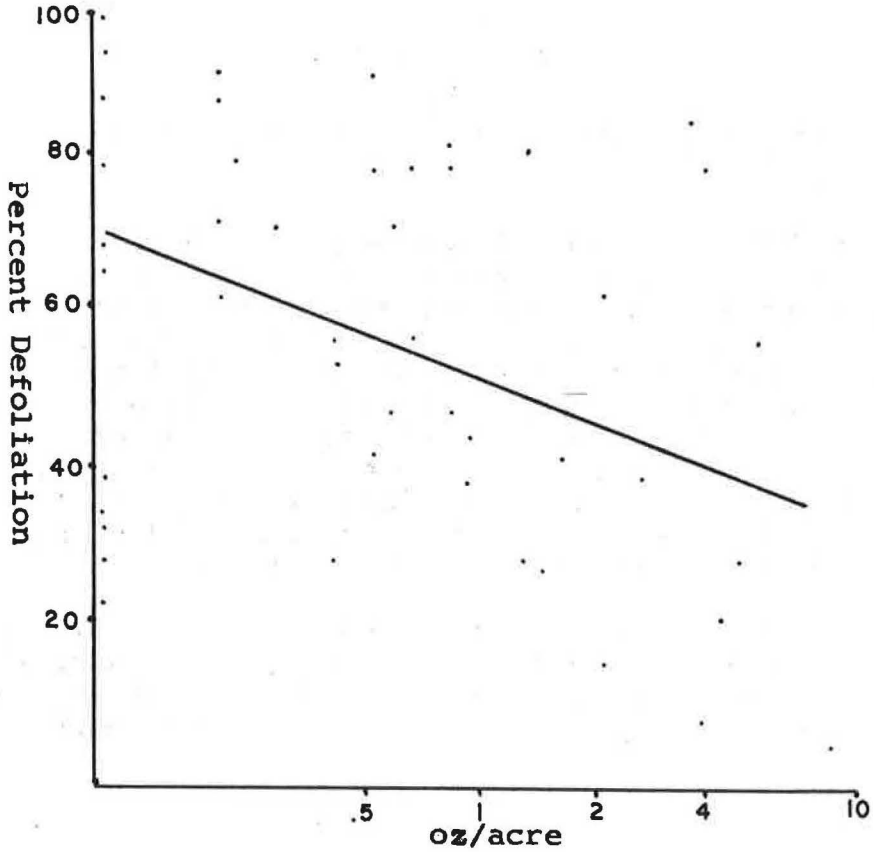

FIGURE 2. Relationship of dosage in first application (X) to percent defoliation (Y). r=-.45 Plots II and V.

population reduction and not foliage preservation. This follows the reported Canadian experience with similar applications of Accothion.

The sum of two applications of spray showed significant relationships with all the other variables on most plots. The relationship with survival is shown in Figure 4 and with defoliation, upper crown, in Figure 5.

Relationships of spray deposit to number of survivors are used in the figures since these relationships were slightly stronger than to percent control. Numbers of survivors and percent control were, of course, strongly related since both were computed from the same population counts. Correlation coefficients between the two variables were above .80. Therefore, conclusions drawn from the relations of spray deposit to survivors apply also to percent control, but in inverse fashion.

In the same sense, only relationship between spray deposit and upper crown defoliation are presented, however, the relationships to lower crown defoliation were similar and actually were statistically stronger. Defoliation in the upper crown is believed to have more importance in terms of tree mortality and damage.

One additional relationship can also be mentioned, that between number of survivors and degree of defoliation, either upper or lower crown. Correlation coefficients varied between .54 and .71 (mean .62) for the various plots. This shows reasonably good agreement between two, independently measured indexes to the effectiveness of the applications of Accothion. Confidence in the results presented is promoted.

A study of the variation in some of the relationships discussed above brought out a point of interest. In the plotted relationship between total spray deposit and number of survivors in plot II, two trends rather than a single one appeared evident. This is illustrated in Figure 6. On investigating further, it was found that all the points but one in the right hand group, the circled points in Figure 6, represented tree clumps that received good spray coverage in both spray applications. All but two points in the left hand group, the uncircled points, on the other hand, received virtually no coverage in the first application, and all of the total dosage was received in the second application. The plotting of these data then, as two trends rather than a single trend, allowed additional conclusions to be drawn on the relative contributions of the first and second treatments alone to budworm population reduction.

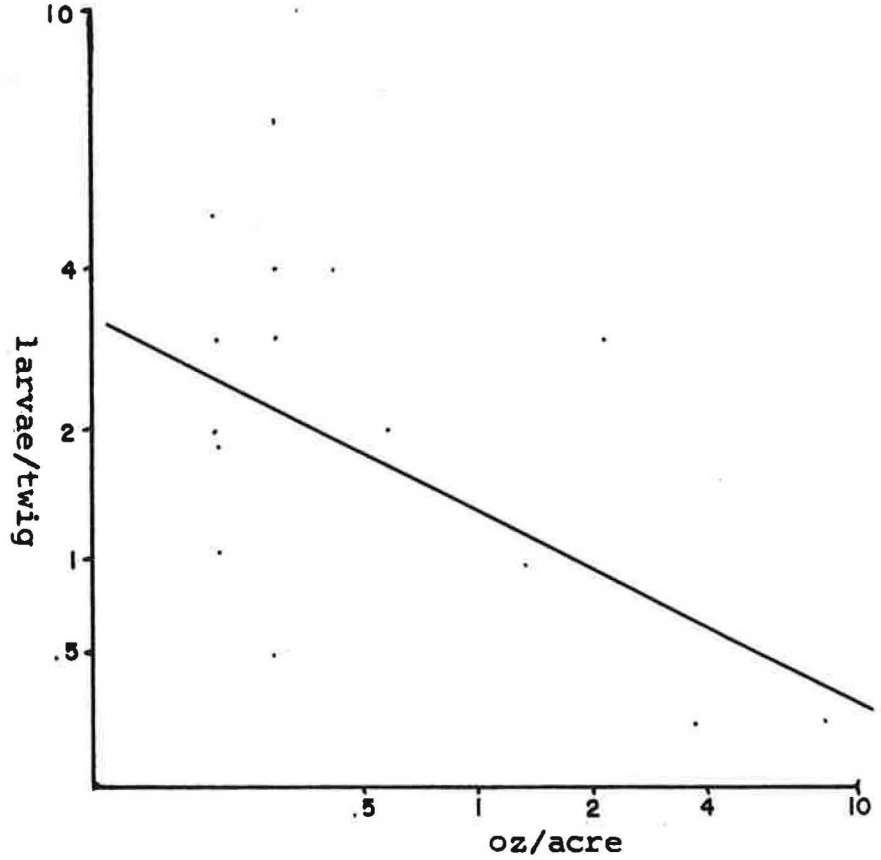

FIGURE 3. Relationship of second application (X) to numbers of spruce budworm survivors (Y). r= -.51 Plot I.

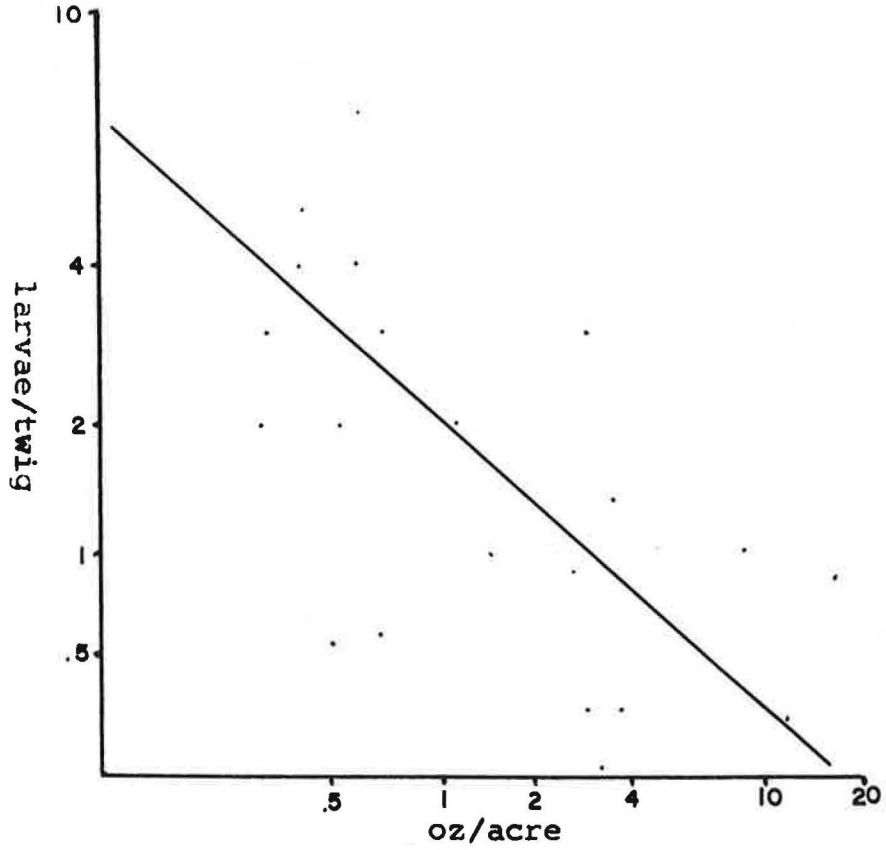

FIGURE 4. Relationship of total spray deposit (X) to numbers of spruce budworm survivors (Y). r= -.59 Plots I and II.